Pestic. Phytomed. (Belgrade), 28(1), 2013, 31–38
DOI: 10.2298/PIF1301031R

UDC: 632.7:634.322(497.16)
Scientific paper

# Dispersion of the Mediterranean Fruit Fly *Ceratitis capitata* Wiedem. (Diptera: Tephritidae) in Mandarin Orchards on Montenegrin Seacoast

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*Received: February 28, 2013*
*Accepted: April 8, 2013*

**SUMMARY**

The Mediterranean fruit fly *Ceratitis capitata* Widem. has been an established pest on the Montenegrin seacoast for more than ten years, although with variable abundance in different years and localities.

From an economic aspect, its most important host in Montenegro is the mandarin unshiu (*Citrus unshiu* Marc.), particularly its cultivar Owari. Dispersion of *C. capitata* in citrus orchards (prevailingly mandarin) was monitored on Baošići, Lastva Grbaljska and Bar localities during 2003 and 2004.

The results of this study showed that, during both years, peripheral-row trees (primarily the first row) in citrus orchards were more exposed to attacks by *C. capitata* than middle and last rows. In 2003, the average number of larvae in mandarin fruits in first rows varied from 11.4±0.59 to 40.1±0.67, from 7.04±0.47 to 28.8±0.48 and from 2.9±0.07 to 17.3±0.54 on the localities of Baošići, Lastva Grbaljska and Bar, respectively. On the same localities, it ranged from 7.4±0.34 to 16.9±0.4, from 0.0 to 18.7±0.32 and from 0.0 to 9.93±0.56 in middle rows, and from 3.0±0.28 to 16.8±0.77, from 0.0 to 20.9±0.38 and from 0.0 to 13.1±0.39 in last rows. Data collected at Baošići, Lastva Grbaljska and Bar in 2003 also suggest that the average number of larvae per mandarin fruit in first rows was 1.78-2.08 times higher than in middle rows, and 1.25-1.77 times higher than in last rows. In 2004, the average number of larvae in mandarin fruits in first rows varied from 7.3±0.27 to 8.3±0.45, from 7.2±0.23 to 17.6±0.59 and from 3.8±0.1 to 8.8±0.25 on the localities of Baošići, Lastva Grbaljska and Bar, respectively. On these localities, it ranged from 1.7 ±0.17 to 3.3±0.19, from 1.1±0.12 to 3.5±0.8 and from 0.0 to 0.8±0.14 in middle rows, and from 1.7±0.17 to 3.6±0.32, from 0.0 to 4.0±0.26 and from 0.0 to 0.2±0.06 in last rows. Data collected in 2004 also showed that the average number of larvae in mandarin fruits in first rows on the same localities was 3.12-15.75 times higher than in middle rows, and 2.94 -6.3 times higher than in last rows.

**Keywords:** Mediterranean Fruit Fly; Dispersion; Mandarin orchards

## INTRODUCTION

The family Tephritidae, the true fruit flies, comprises roughly 4000 species arranged in 500 genera. It is one of the largest and economically most important families of Diptera. The family Tephritidae is represented in all world regions, except Antarctica. The genus *Ceratitis* is endemic to tropical Africa (also known as the Afrotropical region in the Southern Sahara) and contains about 65 species, the majority of which are highly polyphagous (White and Elson-Harris, 1992).

The Mediterranean fruit fly C*eratitis capitata* is the most widespread member of the Tephritidae family (White and Elson-Harris, 1992) with a worldwide distribution. It is a multivoltine species with no diapause to carry it through cold periods with possible subzero temperatures (Christenson and Foote, 1960). It has adapted to various climates and has spread into parts of the world that are beyond the tropical Africa, where the fly is likely to have originated (Fischer-Colbrie and Bush-Petersen, 1989; White and Elson-Harris 1992). According to Carante and Lemaitre (1990) (cit. Israely and Oman, 2005), the adult is the overwintering stage, while Katsoyannos et al. (1998) showed that it is the pupae. On the northern limits of the *C. capitata* range it seems that the fly cannot overwinter in the adult stage, so that some fruit species infested late in the autumn serve as overwintering refuges for larvae (Papadopoulos et al., 1996).

The Mediterranean fruit fly is a highly polyphagous species whose larvae develop in a wide range of different fruits. According to Liquido et al. (1998), it attacks fruits of 374 species from 69 families, while 40% of them belong to the families Myrtaceae, Rosaceae, Rutaceae, Sapotaceae and Solanaceae. It is particularly damaging to fruit crops and vegetables. When appropriate control is lacking, *C. capitata* can damage up to 100% of a crop (Maassen, 1979., cit. Fischer-Colbrie and Busch-Petersen, 1989; Cirio et al., 1972., cit. Fimiani, 1989; Thomas et al., 2001; Umeh et al., 2004). Economic consequences of its presence include not only direct losses in yield and increased control costs, indirect damage (loss of export markets, severe restriction of exports of most commercial fruits as a result of quarantine laws, and the cost of maintaining facilities for fruit treatment and eradication) is usually higher.

The main damage is caused by larvae, which feed on fruit pulp and make it unsuitable for human consumption and processing. Oviposition punctures and larval galleries open the way for moulds and bacteria, which induce decay. Infested fruits often ripen prematurely and drop on the ground. Citrus fruits usually drop prematurely when they are highly infested or additionally weakened by other reasons, such as lack of irrigation, insufficient light or poor soil (Bodenheimer, 1951). Citrus trees are not preferred hosts for *C. capitata* because thick citrus skin can deter egg-laying, and eggs and larvae can be killed by oil in the citrus rind (especially on immature fruits). Higher levels of damage may be expected when citrus fruits are thin-skinned or already damaged, or when there are no other suitable fruits available for egg-laying (www.dpi.vic.gov.au).

The aim of this study was to examine the dispersion of *C. capitata* in citrus (particularly mandarin) orchards and differences in the intensity of fruit infestation depending on row position.

## MATERIAL AND METHODS

The study was conducted in three commercial mixed-fruit orchards on the localities of Baošići, Lastva Grbaljska and Bar on the Montenegrin seacoast. It was done from mid-September to the beginning of November 2003, and from the beginning of the second ten-day period of November until the end of November 2004. The study period **coincided** with the appearance of first visible symptoms on infested mandarin fruits, and lasted until harvest was over. At Baošići, mandarin unshiu (cultivars Wakyama, Chahara, Kawano Wase and Owari) accounts for slightly more than half of the overall 400 citrus trees (mandarin, orange, lemon, grapefruit). Besides mandarin unshiu (the prevailing cultivar is Owari), peaches (*Prunus persica* (L.)- Batsch.), figs (*Ficus carica* L.) and persimmon (*Diospyros kaki* Thunb.) were also grown at Lastva Grbaljska. At Bar, out of 1000 citrus mandarin and orange trees, more than a half were mandarin unshiu (cultivar Owari).

In every locality/orchard, five mandarin trees were choosen in each of three selected rows (two peripheral and one in the middle). Out of these two peripheral-row trees, the outermost row with the southern aspect, i.e. facing the sea, was considered as the first. From each of the five chosen mandarin trees per row, 2-4 fruits were randomly sampled at intervals of 7-15 days, which made 30 to 45 fruits per sampling. Collected fruits were transferred to the laboratory and placed on 1 cm deep layers of sand in plastic containers (30 x 40 cm base, 15 cm height). For each row, two plastic containers were used and held in a thermostat at 25°C. Three times a week, sand in the containers was sieved to recover fully grown larvae (or pupae formed in the meantime) and to count them. For every locality and selected row, the average number of larvae per fruit was counted, and differences in the intensity of attack calculated depending on row in which sampling was done.

## RESULTS

The results of this survey for the year 2003 showed that infestation was highest in the first row on each locality and in each of five mandarin fruit collections (Figures 1, 2 and 3). At Baošići, the average number of larvae per fruit in the first row varied from 11.4±0.59 to 26.7±0.67, which was 1.5 to 3.3 times more than in the middle row, and 1.04 to 3.8 times more than in the last row. At Lastva Grbaljska, the average number of larvae per fruit in the first row varied from 7.4±0.47 to 28.8±0.48, which was 1.4 to 11.3 times more than in the middle row, and 1.3 to 11.3 times more than in the last row. At Bar, the average number of larvae per fruit in the first row varied from 2.9±0.07 to 17.3±0.54, and it was 1.7 to 5.7 times more than in the middle row, and 1.3 to 9.7 times more than in the last row.

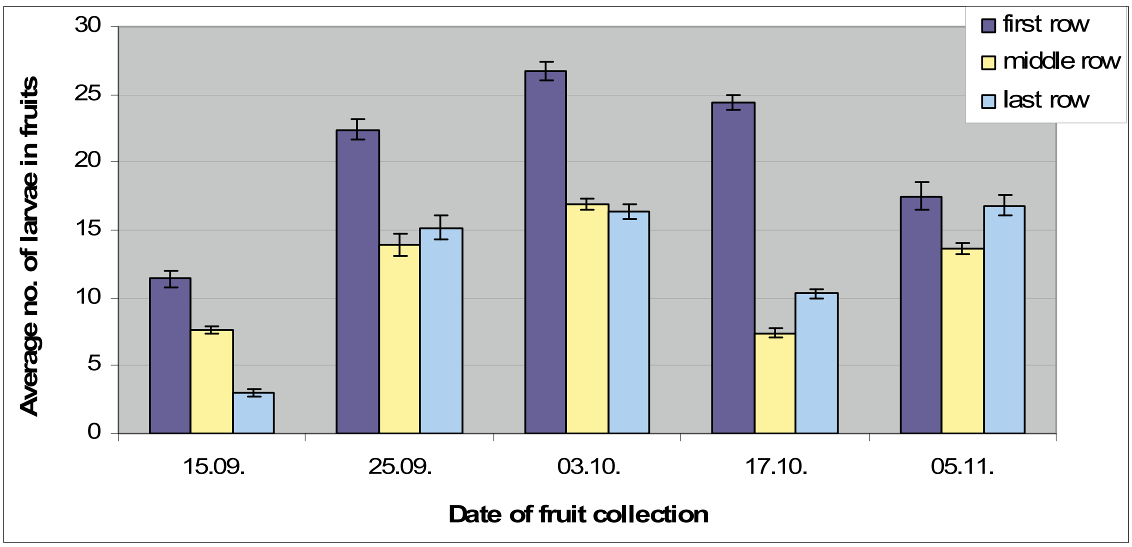


**Figure 1.** Average number of larvae per mandarin fruit on Baošići locality (2003)

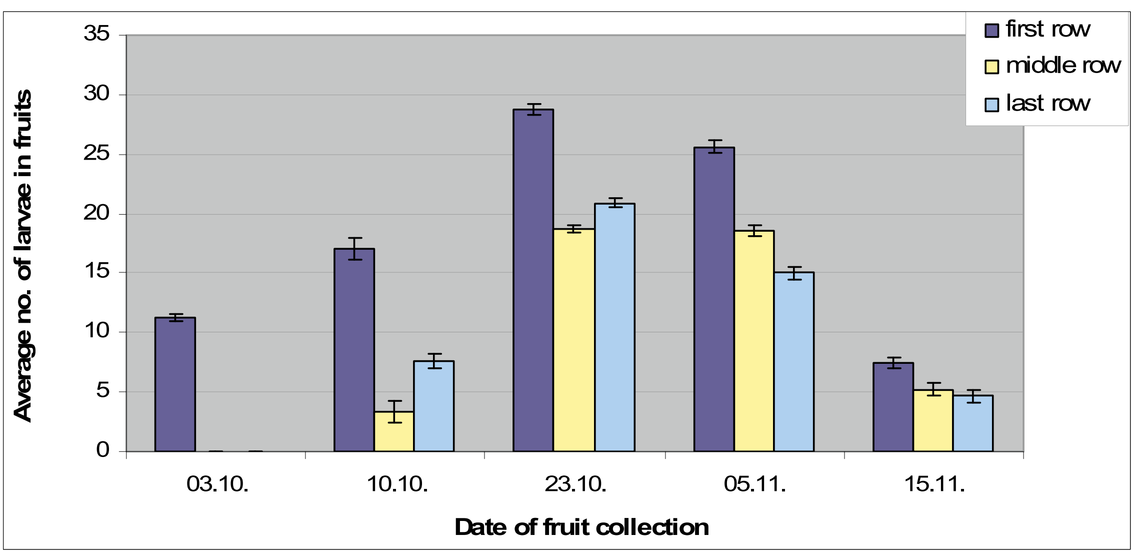


**Figure 2.** Average number of larvae per mandarin fruit on Lastva Grbaljska locality (2003)

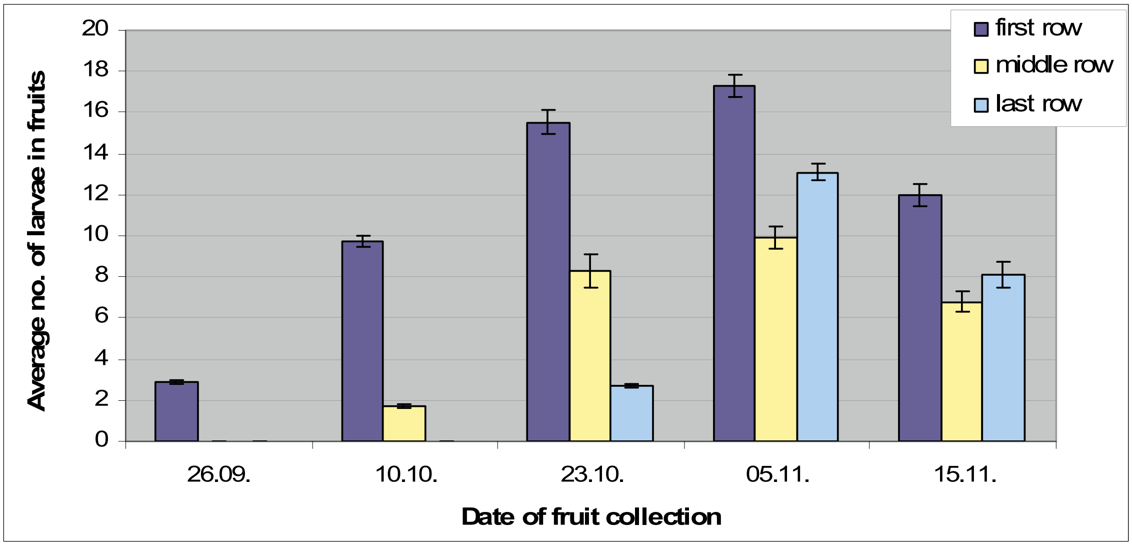


**Figure 3.** Average number of larvae per mandarin fruit on Bar locality (2003)

Data collected in 2003 also show that the average number of larvae per fruit in the first row on all inspected localities throughout the study period was 1.3 to 11.3 times higher than in the middle row, and 1.04-11.3 times higher than in the last row. Also, at the time when the highest level of infestation was reached (at Baošići and Lastva Grbaljska in October), the average number of larvae per fruit in the first row was 26.7±0.67 and 28.8±0.48, or 1.57 to 1.62 and 1.54 to 1.37 times higher respectively than in the middle and last rows. At Bar, the highest level of infestation (17.3±0.54 larvae per fruit) was reached at the beginning of November, which was 1.74 to 1.32 times higher than in the middle and last rows. Even when the intensity of infestation was lowest (during the first fruit collection), the first row on each locality was infested most, or was the only one infested. Consequently, the average number of first-row larvae at Baošići was 11.4±0.59, which was 1.5 to 3.8 times higher than in the middle and last rows, while only the first row was infested at Lastva Grbaljska and Bar. No infestation occured in the middle and last rows.

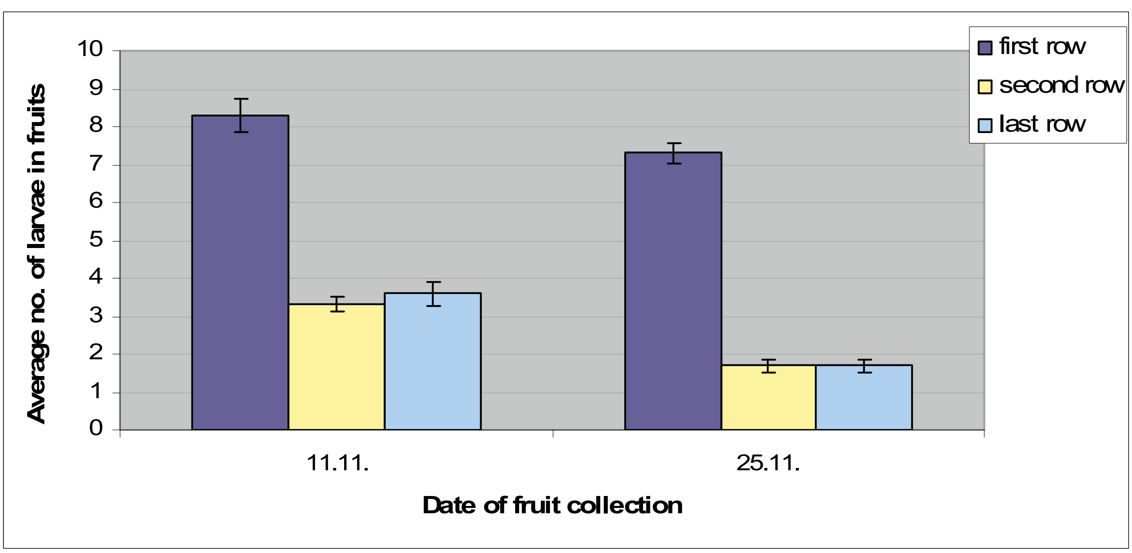


**Figure 4.** Average number of larvae per fruit on Baošići locality (2004)

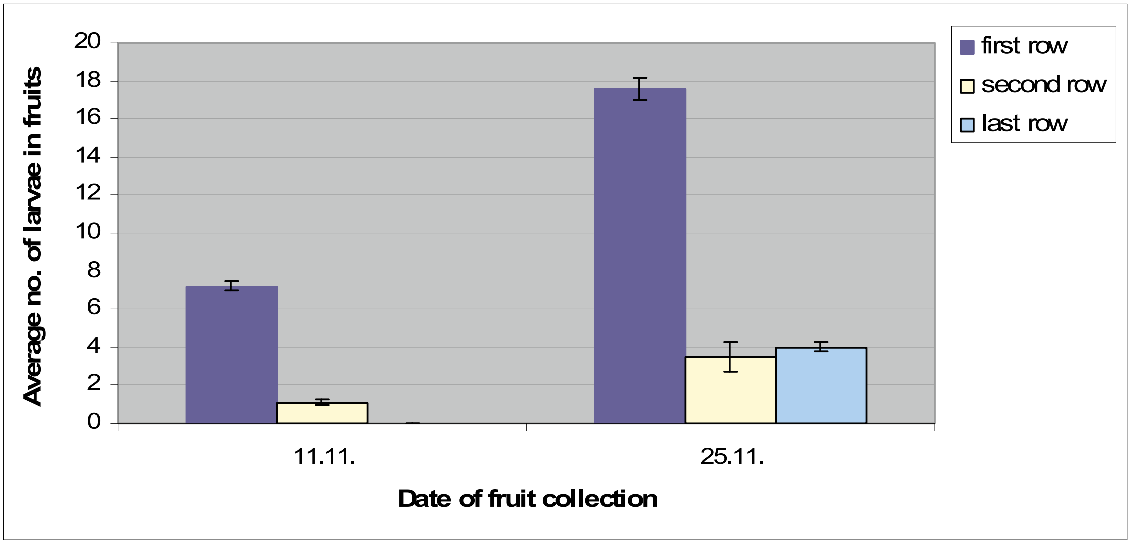


**Figure 5.** Average number of larvae per fruit on Lastva Grbaljska locality (2004)

The results of the study in 2004 showed that infestation was highest in the first row on each locality in both fruit collections (Figures 4, 5 and 6). At Baošići, the average number of larvae per fruit in the first row varied from 7.3±0.27 to 8.3±0.45, which was 2.5 to 4.3 times more than in the middle row, and 2.3 to 4.3 times more than in the last row. At Lastva Grbaljska, the average number of larvae per fruit in the first row varied from 7.2±0.23 to 17.6±0.59, and it was 5.03 to 6.5 times higher than in the middle row, and 4.4 to 7.2 times higher than in the last row. At Bar, the average number of larvae per fruit in the first row varied from 3.8±0.1 to 8.8±0.25, which was 3.8 to 11 times more than in the middle row and 3.8 to 4.4 times more than in the last row.

Data collected during 2004 also show that the average number of larvae per fruit in the first row on all inspected localities during the whole study period was 2.5 to 11 times higher than in the middle, and 2.3-7.2 times higher than in the last row. At the time when the highest infestation was reached (at Baošići at the beginning of the second ten-day period of November) the average number of larvae per fruit in the first row was 8.3±0.45,

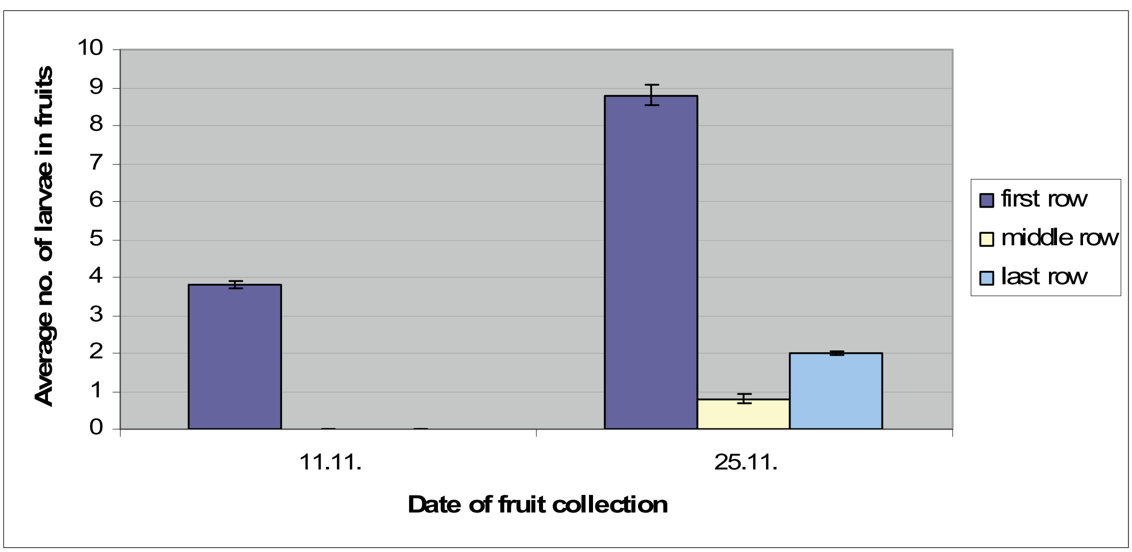


**Figure 6.** Average number of larvae per fruit on Bar locality (2004)

which was 2.5 and 2.3 times more than in the middle and last rows, respectively. At Lastva Grbaljska and Bar, infestation reached maximum during the last week of November, when the average number of larvae per fruit in the first row was 17.6±0.59 and 8.8±0.25, respectively. At Lastva Grbaljska, it was 5.03 to 4.4 times higher than in the middle and last rows, while at Bar it was 4.4 to 11 times higher. Although the first symptoms of fruit attack were observed in November of 2004, and the level of infestation was lower than it was in 2003, the first orchard row on all three inspected localities was infested most. This was particularly evident on the locality of Bar where only the first row was infested in the first inspection,

In all surveyed orchards in 2003, infestation of figs was detected in July and August, persimmon infestation was observed in October, while orange trees were sporadically infested in December. In 2004, the first symptoms of fig infestation were noticed in August and symptoms on persimmon in the second half of October, while no orange infestation was detected at all.

## DISCUSSION

The results of this study showed that *C. capitata* caused the heaviest infestation of mandarin fruits in the first peripheral (outermost) row of trees in orchards. In 2003, when fly dispersion within orchards was wider because of a high population level, the average number of larvae per mandarin fruit in the first row during the whole study period on all inspected localities was 1.3 to 11.3 times higher than in the middle row, and 1.04 -11.3 times higher than in the last row. It was also noticed that the intensity of fruit infestation was more or less similar in the middle-row and last-row trees, but generally the lowest in middle rows. On the other hand, in 2004 when the population level was lower and first symptoms of attack were detected almost two months later than in 2003, the average number of larvae per fruit in the first row was 2.5 to 11 times higher than in the middle row, and 2.3 to 7.2 times higher than in the last row on all inspected localities during the whole study period. Our data coincide with findings reported by Bodenheimer (1951). He showed that *C. capitata* adults usually keep away from the shaded interior of plantations and, as adults are positively phototactic, they can be seen in the orchard to seek the shade of trees as a protection against sun-radiation on the hottest summer days, but always in the brightest parts of an orchard and tree. The author concluded that this habit leads to heavy infestation of marginal rows in dense plantations (such as orange groves), whereas in loose and sunny plantations (peaches and apricots), no such preference is observed. This also coincides with the horticultural practices in citrus orchards in Montenegro, which are, in terms of planting and pruning systems, dense and shady. Bodenheimer (1951) suggested that *C. capitata* is not only positively phototactis, but also heliothermic. This explains why adults normally seek protection from direct sun-radiation in the half-shaded external parts of trees at noon on summer days.

According to the same author, the sequence of hosts is of particular importance because it determines the number of females ready to oviposit in suitable maturing fruits. Additionally, the accessibility of a host is determined by abundance of that host and its spatial distribution. The most abundant fruits are usually the most accessible although rare hosts can be heavily attacked when such plants are grown in places very attractive to the fly.

As *C. capitata* is highly polyphagous, the distance of a suitable fruit crop from the place where the earlier generation had developed determines its accessibility to a high degree. Host plant availability, as well the presence of preferred hosts, creates considerable variation in *C. capitata* abundance. The hot spots seem to be related not only to host species, but also to the ripening sequence and fruit availability (Sciarretta and Trematerra, 2010).

Consequently, fig fruits that are first infested on the Montenegrin seacoast (July and August), although without economic importance, are very important for fly breeding in early summer. This is also the case with the earliest mandarin cultivars (Wakyama or Chahara, which mature around mid- and end of September) and persimmon (matures in October) in terms of breeding of *C. capitata* in early autumn. The availability of these hosts is particularly important for a fly population increase before the mandarin unshiu, the most important host, becomes available for infestation (starting from mid-October). Therefore, mixed fruit orchards with a temporally extended availability of suitable hosts are more preferred by the fly for its development. Our results also showed that on the localities of Baošići (where different mandarin cultivars were present, as well as other citrus species) and Lastva Grbaljska (with different fruit hosts) heavier infestation of mandarin fruits were recorded throughout the study period in both years (regardless of row in orchard) than on the Bar locality where more than a half was mandarin unshiu and one cultivar – Owari.

In order to prevent population build-up, which gradually occurs during August and reaches its peak from mid-September to the end of October (Radonjić, 2008), control measures should be applied in all fruit crops (regardless of their economic importance) as soon as the first signs of fly presence are detected and fruits are in a susceptible phenophase to be attacked (just beginning to ripen). The most common is chemical control (cover spray or bait spray) of *C. capitata* and cultural practices (gathering and destroying all fallen and infested host fruits and mass-trapping with 40-60 traps/ha; traps contain either male or female lures) (www. eppo.int/QUARANTINE/insects/Ceratitis_capitata/CERTCA_ds.pdf; Navarro, 2002).

The phototactic and heliothermic features of the fly, as well the horticultural practices in Montenegrin citrus (mostly mandarin) orchards, explain our results and the attractiveness of outer, particularly first-row trees for adults. Awareness of a strong positive phototactic behavior and heliothermic feature of *C. capitata* are important for a control strategy, particularly the trapping system, because there is always a high probability of the earliest captures to occur in peripheral-row trees. Therefore, population monitoring with pheromone or protein lures and the following trapping procedures (IAEA, 2003) are always done by placing traps on trees in peripheral rows (Delrio and Ortu, 1988; Cohen and Yuval, 2000) as well as in other rows within an orchard.


## ACKNOWLEDGEMENT

This paper is a segment of the Ph.D. thesis titled The Mediterranean Fruit Fly *Ceratitis capitata* Wiedem. (Diptera, Tephritidae) on the Montenegrin seacoast and its impact on agricultural production, which was funded by the Ministry of Education and Science of Montenegro.


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# Mediteranska voćna muva *Ceratitis capitata* Wiedem. (Diptera, Tephritidae) – disperzija u zasadima mandarine na području Crnogorskog primorja

**REZIME**

Mediteranska voćna muva *Ceratitis capitata* Widem. se smatra odomaćenom na Crnogorskom primorju već više od deset godina, premda sa izraženim oscilacijama u brojnosti kako po godinama, tako i u različitim lokalitetima.

U ekonomskom smislu, njen najznačajniji domaćin u Crnoj Gori je mandarina unšiu (*Citrus unshiu* Marc.), a posebno sorta Owari. Tokom 2003. i 2004. godine, u lokalitetima Baošići, Lastva Grbaljska i Bar praćena je disperzija *C. capitata* u zasadima citrusa u kojima je brojnošću dominirala mandarina unšiu.

Rezultati dvogodišnjih istraživanja ukazuju da muva jače napada plodove u perifernom redu voćnjaka u odnosu na srednji i poslednji red. U 2003. godini je utvrđno da je u lokalitetima Baošići, Lastva Grbaljska i Bar prosečan broj larvi u plodovima mandarine u prvom redu varirao od 11,4±0,59 do 40,1±0,67, od 7,04±0,47 do 28,8±0,48 i od 2,9±0,07 do 17,3±0,54. U istim lokalitetima zabeleženo je prosečno od 7,4±0,34 do 16,9±0,4, od 0,0 do 18,7±0,32 i od 0,0 do 9,93±0,56 larvi u plodovima koji su uzorkovani u srednjem redu, odnosno od 3,0±0,28 do 16,8±0,77, od 0,0 do 20,9±0,38 i od 0,0 do 13,1±0,39 larvi u plodovima u poslednjem redu. Rezultati iz 2003. godine, takođe, ukazuju da je u ispitivanim lokalitetima prosečan broj larvi u plodu mandarine bio 1,78-2,08 puta veći u prvom redu u odnosu na srednji, odnosno 1,25-1,77 puta veći nego u poslednjem redu. U 2004. godini je utvrđno da je u lokalitetima Baošići, Lastva Grbaljska i Bar prosečan broj larvi u plodovima mandarine u prvom redu varirao od 7,3±0,27 do 8,3±0,45, od 7,2±0,23 do 17,6±0,59 i od 3,8±0,1 do 8,8±0,25. U istim lokalitetima zabeleženo je prosečno od 1,7 ±0,17 do 3,3±0,19, od 1,1±0,12 do 3,5±0,8 i od 0,0 do 0,8±0,14 larvi u plodovima koji su uzorkovani u srednjem redu, i od 1,7±0,17 do 3,6±0,32, od 0,0 do 4,0±0,26 i od 0,0 do 0,2±0,06 larvi u plodovima u poslednjem redu. Rezultati iz 2004. godine, takođe, ukazuju da je u lokalitetima Baošići, Lastva Grbaljska i Bar utvrđeno da je prosečan broj larvi u plodovima mandarine bio 3,12-15,75 puta veći nego u srednjem redu, odnosno 2,94-6,3 puta veći nego u poslednjem redu.

**Ključne reči**: Mediteranska voćna muva; disperzija; zasadi mandarine